CERTIFICATION OF ENGLISH LANGUAGE
TRANSLATION OF PRIORITY DOCUMENT

I, Kentaro Higuchi, hereby declare and state that I am knowledgeable of each of the Japanese and English languages. I hereby certify that the attached English language translation is a complete and accurate translation of Japanese Patent Application Number 10-248902 entitled Stage Device and Exposure Device.

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Date

Signature

Kentaro Higuchi
Typed Name

[Name of Document] Specification

[Title of the Invention] Stage Device and Exposure Device

[Scope of Claims]

[Claim 1]

A stage device having a first stage movably supporting an object, and a drive mechanism that drives the first stage at least in a first direction, the first stage having a first portion that has at least a movable part of the drive mechanism and a second portion that holds the object, the stage device comprising:

a first position measuring device that measures a position of the first portion in a predetermined measurement direction; and

a first stage control system that controls the drive mechanism to control at least the position of the object in the first direction, based on a measurement result of the first position measuring device.

[Claim 2]

The stage device of claim 1, further comprising a second position measuring device that measures a position of the second portion in a predetermined measurement direction, wherein the first stage control system further controls the drive mechanism based on measurement results of the first and second position measuring devices to compensate position errors of the first and second portions in the first direction.

[Claim 3]

The stage device of claim 1 or 2, wherein the first and second portions are integrally formed.

[Claim 4]

The stage device of claim 1, further comprising:

a second stage different from the first stage;

a second position measuring device that measures a position of the second portion in the predetermined measurement direction; and

a second stage control system that controls the second stage so that the first stage and the second stage have a predetermined positional relationship, based on a measurement result of the second position measuring device.

[Claim 5]

An exposure device for transferring a predetermined pattern on a plate, comprising

the stage device of any one of claims 1-3, wherein the plate is placed on the second portion of the first stage.

[Claim 6]

An exposure device for transferring a pattern of a mask by synchronously moving a mask and a plate, comprising

the stage device of claim 4, wherein one of the first stage and the second stage is a mask stage that holds the mask, and the other is a plate stage that holds the plate.

[Detailed Description of the Invention]

[0001]

[Industrial Field of the Invention]

The present invention relates to exposure devices used in lithographic processes for the manufacture of liquid crystal displays, integrated circuits, thin film magnetic heads, etc., and to stages suitable for use with such exposure devices.

[0002]

[Conventional Art]

Lithographic processes utilized during the manufacture of liquid crystal displays, integrated circuits, and other similar devices usually involve exposure devices. Such exposure devices have been used to image a mask pattern onto a plate. Such exposure devices for liquid crystal include a stationary exposure type projection exposure devices of step and repeat type (often referred to as a "liquid crystal stepper") and batch transfer type scanning exposure devices which scan a mask stage and a plate stage in the same relative direction with respect to a projection optical system and transfer a pattern of a mask onto a plate (e.g., a glass plate). Recent developments have been made in regard to exposure devices as a result of increased demand for larger liquid crystal displays, etc. Accompanying such increases, plate sizes within exposure devices of a step and scan type (scanning stepper) have correspondingly increased. Accordingly, scan type exposure devices have been developed which are capable of exposing a large surface compared to a stepper, and which perform exposure of plural shots with respect to one plate.

[0003]

Fig. 5 shows mainly a stage system of a batch transfer type (or step and scan type) scanning exposure device. Fig. 6 shows a structure of the stage control device mainly structured by a control device (controller) 101 shown in Fig. 5.

[0004]

In Fig. 5, a mask stage MST and plate stage PST are respectively supported on air pads (not shown in the drawing) on an upper surface plate 102a and a lower surface plate 102b which make up the body column 102 which supports the projection optical system PL. The mask stage and plate stage are moved by linear motors 104, 106 in right and left directions of the drawing (hereinafter referred to as "scanning direction"). The stator 104a of the linear motor 104 which drives the mask stage MST is fixed to the upper surface plate 102a, and its moving element 104b is fixed to the mask stage MST. Moreover, the position of the mask stage MST in the scanning direction is constantly measured by means of a laser interferometer 108 which is fixed to the body column 102.

[0005]

The stator 106a of the linear motor 106 which drives the plate stage PST is fixed to the lower surface plate 102b, and its moving element 106b is fixed to the plate stage PST. The plate stage PST is equipped with a moving table 110 to which moving element 106b is fixed, and a plate table 116 which is loaded on this moving table 110 via a $Z \cdot \theta$ movement mechanism 114. The position of the plate table 116 in the scan direction is constantly measured by means of a laser interferometer 112 which is fixed to the body column 102.

[0006]

The arrangement of the stage control device 101 is now described with reference to Fig. 6.

[0007]

As shown in Fig. 6, a position control loop of the plate stage PST includes interferometer 112, a subtractor 118, a plate stage servo operating unit 120, a plate stage drive amplifier 122, and linear motor 106 which is driven by the drive signal S2 output from this amplifier 122. Moreover, plate stage position information S1 from the interferometer 112 is fed back as input to the plate stage servo operating unit 120 via a differencing unit 124. Accordingly, a speed control loop is constituted as the inner loop (minor loop) of the position control loop. The reference position is input from the reference value output unit 126 with respect to the subtractor 118 of the aforementioned position control loop. By means of the position and speed control loop of the plate stage PST constituted in this way, position and speed control are performed of the plate stage such that the position deviation, which is the difference of the reference position and the output of the interferometer 112, becomes zero.

[0008]

Similarly, a position control loop of the mask stage MST includes interferometer 108, a subtractor 128, a mask stage servo operating unit 130, a mask stage drive amplifier 132, and the linear motor 104 which is driven by the drive signal S4 output from this amplifier 132. The plate stage position information S1, which is the output of the interferometer 112 with respect to the subtractor 128 of this position control loop, is input as the reference position. Accordingly, by means of the position control loop of the mask stage MST, slave control of the mask stage MST is performed with respect to the plate stage PST, such that the positional deviation, which is the difference of the output S 1 of the interferometer 112 and the output S3 of the interferometer 108, becomes zero.

[Problems to be Solved by the Invention]

[0009]

In general, in a closed loop control system, the bandwidth (the frequency at which the gain of the closed loop frequency characteristic becomes $\sqrt{(1/2)}$ times of the low frequency gain as the frequency ω 0, when expressed in dB, falls 3 dB from the low frequency gain of $\omega \to 0$) provides an idea of to what frequency component the system can truly follow. However, in this specification, instead of this bandwidth, the frequency at which the gain starts to decrease from a low frequency gain (normally 0dB) at $\omega \to 0$, is defined as a response band (or servo response band).

[0010]

With a stage control system as shown in Fig. 6, for example, by means of the response band of the plate stage position and speed control loop, during the fixed speed control (uniform speed control) of the plate stage performed in the scanning exposure time the variable speed, adjustment characteristics, speed fluctuation, or during the position setting control of the plate stage performed in the shot interval stepping time, in the case of step and scan type of exposure device, the variable speed, speed adjustment, position setting accuracy and the like, the plate stage control performance is set.

[0011]

Nevertheless, in the aforementioned prior art stage control device, the position of the plate table 116, which is separated from the linear motor 106 that is the drive source, is measured by means of the interferometer 112, and between this plate table 116 and the moving table 110 on which the moving element 106b of the linear motor 106 is fixed, a Z · θ drive mechanism 114

exists, which is independent from position control of the scanning direction of the plate stage, and low frequency mechanical natural vibrations are included in the plate stage position and speed control loop as a resonant mode. In this case, for example, during drive of the plate stage, when the resonant frequency rises beyond the aforementioned Z · θ drive mechanism 114, because the position information of the plate table 116, which received the effects of this resonant frequency, is input as feedback into the position control loop, because it becomes difficult to control the position and speed of the plate stage, it is necessary to prevent such an effect. Accordingly, in prior art stages control systems, the response band of the position and speed control loop of the plate stage cannot be made sufficiently wide, and as a result there was the disadvantage that the plate stage control performance cannot be made sufficiently high.

[0012]

In Figs. 7(A) and (B), in the case that the frequency of the aforementioned resonant vibration is 60 Hz, in the prior art stage control system the frequency response characteristics and phase characteristics of the position control loop of the plate stage PST are respectively shown. As is clear from Fig. 7, the response band of the plate stage became about 10 Hz.

[0013]

Moreover, the result that the plate stage control performance could not be made sufficiently high, overshoot arising after the end of variable speed of the plate stage PST (response of the system exceeding the expected value in the case that a sudden change occurred in the input; overshooting amount), undershoot (the reverse of overshoot; the response does not reach the expected value, in the case of a sudden change in the input; undershoot amount) becomes large, and it was an inconvenience that the performance of the mask stage slave control became poor, performing the plate stage position as a position instruction.

[0014]

However, a problem similar to the aforementioned plate stage movement problem arises in an XY stage of a 2-stage structure which loads an X stage via a drive mechanism of the X stage on the upper portion of the Y stage, or in the fine movement stage loaded via the upward drive mechanism of the coarse movement stage, in the control system of a reticle stage of the so-called coarse-fine movement structure.

[0015]

The present invention solves the problems mentioned above and has as a first object to provide a stage control device for use with an exposure device that delivers increased stage control performance.

[0016]

A second object of the present invention is to provide an exposure device that delivers increased throughput and pattern transfer accuracy.

[0017]

[Problem Resolution Means]

Accordingly, the present invention provides a stage device having a first stage (PST) which movably supports an object (P) and a drive mechanism (16) which drives the first stage in at least a first direction. The first stage has a first portion (22) that has at least a movable portion (16b) of the drive mechanism and a second portion for supporting the object. The first stage device is configured with a first position measuring device (24) which measures the position of the first portion in a predetermined measurement direction. The stage device further includes a first stage control system (L1) which controls the drive mechanism to control the position of the object in at least a first direction based on a measurement result obtained by the first position measuring device.

[0018]

According to this, the first stage has the first portion having at least a movable part of the drive mechanism, and a second portion that supports an object, and is driven by the drive mechanism at least in the first direction. Moreover, the first stage control system controls the drive mechanism to control the position of the object in at least the first direction, based on the measurement result of the first position measuring device.

[0019]

That is, because the first stage control system controls the drive mechanism based on the position measurement result of the first portion having the movable part of the drive mechanism, rather than the position measurement result of the second portion that supports the object that is the subject of the position control, even if mechanical natural vibration caused by any reason is generated between first and second portions, for example, since the mechanical natural vibration is not included in the first stage control system as a resonance mode, as a result the response

band of the first stage control system can be widened. Therefore, the control performance of the stage (first stage) can be increased by avoiding effects of the mechanical natural vibration.

[0020] Here, "the first portion that has at least a movable part of the drive mechanism" includes cases where the first portion of the stage is structured by a movable part of the drive mechanism, and cases where the first portion and the movable part are separate members but the movable member is fixed on the first portion. Therefore, a measurement point of the first measuring device can be set in any of the movable part of the separate members.

[0021]

Moreover, the measurement direction of the first portion measuring device is preferably the same direction as the first direction. However, it can be other directions (but excluding a direction perpendicular to the first direction). It is because, in that case, the position of the first portion the first direction can be determined by calculations of trigonometric functions (the same in the second position measuring device described later).

[0022]

In the above described first stage device, when the second position measuring device (25) that measures a position of the second portion (19) in a predetermined measurement direction is equipped, the first stage control system (L1) can further control the drive mechanism (16) based on the measurement result of the first and second measuring device (24, 25) to compensate position errors of the first portion (22) and the second portion in the first direction. In that case, because the first stage control system can further control the drive mechanism based on the measurement result of the first and second measuring device to compensate position errors of the first portion and the second portion in the first direction, as a result the second portion and thus the object supported thereon can be accurately positioned at a desired position.

[0023]

Furthermore, the first and second portions structuring the first stage can be formed by separate members and relatively connected with a certain degree of freedom. However, the first and second portions can be integrally formed. This "integrally formed" includes, of course, integral formation by the same member but also a case where separate members are strongly fixed to each other.

[0024]

Moreover, the second stage device of this invention is equipped with a second stage (MST) different from the first stage (PST), a second position measurement device (25) that

measures a position of the second portion in the predetermined measurement direction, and a second stage control system (L2) that controls the second stage so that the first stage and the second stage have a predetermined positional relationship, based on a measurement result of the second position measurement device.

[0025]

According to this, since position control performance of the first stage can be increased by the first stage device, position errors caused by overshoot and undershoot after acceleration and deceleration of the first stage can be minimized. Therefore, the errors included in the measurement results of the position of the second portion in the predetermined measurement direction by the second position measuring device can be decreased, and the control performance of the second stage for adjustment of the positional relationship of the second stage with respect to the first stage that is performed based on the measurement result of the second position measuring device can be increased.

[0026]

Moreover, the first exposure device according to this invention is an exposure device for transferring a predetermined pattern on a plate, and is equipped with the first stage device, and the plate is placed on the second portion (19) of the first stage (PST).

[0027]

According to this, by the first stage device, as described above, as a result of the fact that the control performance of the first stage can be increased by an increase of the response band, it is possible to increase the adjustment time for positioning the plate supported on the second portion of the first stage and thus increase the positioning accuracy. Therefore, it is possible to have both increase of throughput and increase of transfer accuracy of the pattern.

[0028]

In addition, the second exposure device according to this invention is an exposure device for transferring a pattern of a mask (M) by synchronously moving a mask and a plate (P), and is equipped with the second stage device, and one of the first stage and the second stage is a mask stage (MST) that holds the mask, and the other is a plate stage (PST) that holds the plate.

[0029]

According to this, in the above described second stage device, position control performance of the first stage using the first stage control system can be increased, while the control performance of the second stage for adjusting the positional relationship of the second

stage with respect to the first stage using the second stage control system can be increased. Therefore, when one of the first and second stages is a mask stage on which a mask is placed, and the other is a plate stage on which a plate is placed, synchronous adjustment time and fixed speed synchronization control of the mask stage and the plate stage at the time of scanning exposure can be performed with higher accuracy. As a result, increase of throughput and increase of accuracy of superimposing the mask and the plate (transfer accuracy of the pattern) can be achieved.

[0030]

[Preferred Embodiment of the Invention]

The present invention is now discussed with reference to Figs. 1-4. Referring now to Fig. 1, depicted therein is a schematic diagram of a preferred embodiment of an exposure device 10 provided in accordance with the present invention. Exposure device 10 is an equal magnification batch transfer scanning type exposure device for liquid crystal, which transfers a pattern formed on a mask M onto a plate P by means of correspondingly scanning a mask M, containing a liquid crystal display element pattern, and a glass plate (termed "plate" below) P as a plate (and object) supported on a plate stage PST as a first stage, by relatively scanning them in the same direction and at the same speed along a predetermined scanning direction (here, taken as the Y direction right and left directions of the drawing in Fig. 1).

[0031]

Exposure device 10 is equipped with an illuminating system IOP which illuminates a predetermined slit shaped illumination region (region of elongated rectangular form or circular arcuate form extending in the X axis direction in Fig. 1) on the mask M by an exposure illumination light IL and which is on a mask stage MST as a second stage which moves in the Y axis direction and which supports the mask M formed with the pattern, a projection optical system PL that projects onto the plate P exposure illuminating light IL which has passed through the aforementioned illumination region portion of mask M, a plate stage PST that moves in the Y axis direction and supports plate P, a body column 12 that movably supports mask stage MST and plate stage PST and holds projection optical system PL, and a control device 11 which controls both the aforementioned stages MST, PST.

[0032]

The aforementioned illuminating system IOP may be similar or like one disclosed in Japanese Laid-Open Patent Publication Number JP-H9-320956. Such an illuminating optical

system IOP includes a light source unit, a shutter, a secondary light source forming optical system, a beam splitter, a condensing lens system, a visual field diaphragm (blind), and an imaging lens system (all omitted from drawings), to uniformly illuminate, as described next, the aforementioned slit shaped illumination region on a mask M supported and positioned on a mask stage MST.

[0033]

The mask stage MST, by means of air pads not shown in the drawing, is float supported with a few microns clearance above the upper surface of an upper surface plate 12a constituting the body column 12, and is driven in the Y axis direction by means of a drive mechanism 14.

[0034]

Because a linear motor is used here as the drive mechanism 14 which drives the mask stage MST, this drive mechanism is termed below the "linear motor 14." The stator 14a of linear motor 14 is fixed to the upper portion of the upper surface plate 12a, and extends along the Y axis direction. Moreover, the movable element 14b of the linear motor 14 is fixed to the mask stage MST. Moreover, the position of the mask stage MST in the Y direction is normally measured by means of a laser interferometer 18 (termed below, "mask-use interferometer") for mask stage position measurement; with reference the projection optical system PL, for example, with a resolving power of a few nm. The Y direction information S3 of the mask stage MST measured by the interferometer 18 is supplied to the control device 11 (see Fig. 2).

[0035]

The aforementioned projection optical system PL is arranged below the upper surface plate 12a of the body column 12 and is supported by means of a support member 12c which is part of column 12. The projection optical system PL is used to project an erect image. Accordingly, when the aforementioned slit shaped illumination region on the mask M is illuminated by means of exposure using illuminating light IL from the illuminating optical system IOP, the equal magnification image (partial erect image) of a circuit pattern of its illumination region portion on mask M becomes projected to the conjugate region to be exposed in the aforementioned illumination region on plate P. Furthermore, for example, as disclosed in JP-H7-57986, the projection optical system PL may constitute plural sets of equal magnification erect image projection optical system units.

[0036]

The aforementioned plate stage PST, arranged below the projection optical system PL, is float supported with a clearance of a few microns above the upper surface of the lower surface plate 12b which constitutes the body column 12 by means of air pads not shown in the drawing. This plate stage PST is driven in the Y axis direction by means of a linear motor 16 as a drive mechanism. The stator 16a of this linear motor 16 is fixed to the lower surface plate 12b, and extends along the Y axis direction. The moving element 16b as the moving unit of the linear motor 16 is fixed to the bottom portion of the plate stage PST.

[0037]

The plate stage PST is equipped with a moving table 22 as a first portion to which the moving element 16b of the aforementioned linear motor 16 is fixed, and a $Z \cdot \theta$ mechanism 20 loaded on this moving table 22, and a plate table 19 as a second portion located on the upper portion of the $Z \cdot \theta$ mechanism 20. A plate P is loaded on this plate table 19 and is held firm by a vacuum chuck not shown in the drawing. Moreover, this plate table 19 becomes suitable for fine driving in the Z up and down direction and rotary direction by means of the $Z \cdot \theta$ drive mechanism 20.

[0038]

The position of the aforementioned moving table 22 in the Y axis direction is usually measured by means of a first interferometer 24 for first plate as a first position measuring device fixed to the body column 12 with the projection optical system PL as a reference at a predetermined resolving power, for example, a resolving power of a few nm. The Y direction position information S0 of the moving table 22 measured by this first interferometer 24 for table is supplied to the control device 11 (see Fig. 2).

[0039]

Moreover, the position in the Y axis direction of the aforementioned plate table 19 is usually measured by means of a second interferometer 25 for plate as a second position measuring device fixed to the body column 12 with the projection optical system PL as a reference at a predetermined resolving power, for example, a resolving power of a few nm.

[0040]

As this second interferometer 25 for plate, here a 2-axis interferometer is used which illuminates with respect to the plate table 19, two measuring beams in the Y axis direction, spaced apart a predetermined distance L in the X axis direction which is at right angles to the Y

axis direction (at right angles to the plane of the paper in Fig. 1); the measurement value of each measuring axis is supplied to the control device 11 (and via this to a main control device, not shown in the drawing). When the measurement values of the respective measuring axes of this second interferometer 25 for plate are denoted by Y1, Y2, the position of the plate table 19 in the Y axis direction can be found by means of the equation $Y = (Y1 + Y2)/2$, and the rotation amount of the plate table 19 around the Z axis can be found by means of the equation $\theta = (Y1 - Y2)/L$, but in the description below, other than in particularly necessary cases, the aforementioned Y from the second plate use interferometer 25 is output as Y position information S1 of the plate table 19.

[0041]

Furthermore, in this embodiment, a focus position detection system not shown in the drawing which measures the Z direction position of the plate P, for example, an oblique incident light type focus position detection system, is fixed to the support member 12c which supports the projection optical system PL, the Z position information of the plate P from this focus position detection system is supplied to a main control device not shown in the drawing by the main control device, for example, during scanning exposure, the auto-focus operation comes to be effected causing the Z position of the plate P to coincide with the imaging surface of the projection optical system PL via the $Z \cdot \theta$ drive mechanism 20, based on this Z position information. Furthermore, it becomes the main control device based on the aforementioned θ (amount of rotation around the Z axis), controlling the rotation of the plate P during scanning exposure via the $Z \cdot \theta$ drive mechanism 20, or based on the rotation error of the two, found from the alignment result of the mask M and the plate P.

[0042]

Fig. 2 is a block diagram of a stage control device mainly structured by the control device 11, and Fig. 3 is a control block diagram of a control system corresponding to the stage control device.

[0043]

The control device 11 is equipped with a reference value output unit 26 which outputs a reference position P_{ref}, a command speed V_{ref}, and a command acceleration α_{ref}; and a subtractor 28 which calculates the difference (position deviation) of the reference position P_{ref} output from this reference value output unit 26 and the Y position information S0, which is output from the first interferometer 24 for plate, namely the actual position in the Y axis direction of the moving

table 22; a plate stage servo operator 32 which inputs the output from this operator 28 and the command speed V_{ref} as a feed-forward input from the reference value output unit 26; an adder 55 which adds the output of this plate stage servo operating unit 32 and the control amount corresponding to the command acceleration α_{ref} feed-forward input from the reference value output unit 26; a plate stage drive amplifier 36 which converts the output of this operator 55 to a plate stage drive signal S2 and provides it to the linear motor 16; and a difference unit 40 which differences the position information S0 and inputs to the plate stage servo unit 32. The difference unit 40 finds the rate of change of the position information S0 by time excluding in sampling clock intervals, the difference of the value of the previous sampling time and the value of the present sampling time, namely the speed of the moving table 22.

[0044]

Moreover, the control device 11 is equipped with a subtractor 44 which calculates the position deviation in the Y axis direction of the mask stage MST and the plate table 19 which is the difference of the two, inputting the Y position information S3 output from the interferometer 18 for mask use and the Y position information S1 which was output from the second interferometer 25 for plate use; and a mask stage servo operating unit 46 which inputs the output from the subtractor 44; and a mask stage drive amplifier 48 which converts the output of this mask stage servo operating unit 46 into a mask stage drive signal S4 and provides this to the linear motor 14.

[0045]

The aforementioned plate stage servo operating unit 32, for example, as shown in Fig. 3, can be constituted by a P controller 50 which performs a (proportion) control operation as an operation signal the position deviation from the operator 28; and a subtractor 52 which calculates the speed deviation which is the difference of the speed command value output from this P controller 50 and the output of the integrating circuit 56 of Fig. 3; corresponding to the output of the difference unit 40 of Fig. 2, that is, the actual speed of the moving table 22); and a PI controller 54 which performs control operation combining (proportion + integration) control operation (PI control operation) and phase lead compensation control, with the speed deviation which is the output of this operator 53 as the operating signal. Furthermore, the PI controller 54 is a phase lead compensation circuit, for example, a built-in CR circuit.

[0046]

As shown in Fig. 2, the first interferometer 24 for plate, the subtractor 28, the difference unit 40, the plate stage servo operating unit 32, the plate stage drive amplifier 36 and the linear motor 16 make up a multiple loop control system Ll is shown in Fig. 3, which has the position control loop LL1 which performs proportional control of the position of the plate stage PST, and the speed control loop LL2 constituting its inner loop (minor loop) which performs the aforementioned combined operation of the PI control operation and phase lead compensation control. By means of multiple loop control system L1, the plate stage position and speed control system Ll is constituted as the first stage control system. Here, that the plate stage position and speed control system L11 is as a multiple loop control system is in order, for example, to provide improvement of the steady speed deviation and the like.

[0047]

The aforementioned mask stage operating unit 46, for example, as shown in Fig. 3, can be constituted by means of a PI controller which performs PI control operation with the position deviation from the subtractor 44 as an operating signal.

[0048]

In the present preferred embodiment, the mask use interferometer 18, subtractor 44, the mask stage servo operating unit 46, the mask stage drive amplifier 48, and the linear motor 14, as shown in Fig. 2, make up the mask stage position control system L2 which is constituted as a second stage control system which performs position control of the mask stage MST, considering as a reference value the Y position information S1 of the plate table 19 from the second interferometer 25 for plate as shown in Fig. 3. By means of this, mask stage position control system L2 controls of the mask stage MST with respect to the plate stage PST, with the Y position information S1 of the plate table 19 as the reference input. Furthermore, for reasons similar to those mentioned above, it makes no difference if the mask stage control system is made as a multiple loop control system similarly to the plate stage position and speed control system L1.

[0049]

Furthermore, in the preferred embodiment shown in Fig. 2 and, in particular, the calculating unit 38 that determines the position difference (error) of the position of the plate table 19 and the position of the moving table 22 based on the position information S1 and the position information S0, is disposed in the control device 11 to calculate the instruction value in order to

compensate this error, and the output of this calculating unit 38 is connected via a switch circuit 42 to an adder 30 arranged between the subtractor 28 and the plate stage servo operating unit 32. The switch circuit 42 is normally OFF and is set ON as necessary by the main control device not shown in the drawing, and when this switch circuit 42 is ON, the difference of the position of the plate table 19 and the position of the moving table 22 is integrated and input to the above plate stage position and speed control system L1 (specifically, the position control loop LL1) as a compensation value (instruction value to compensate the aforementioned error). Namely, a compensation system C1 is constituted by means of the calculating unit 38 and the switch circuit 42, and compensates for the difference (error) of the position of the plate table 19 and the position of the moving table 22.

[0050]

Furthermore, the control device 11 is constituted by a microcomputer and of course the function of each portion of Fig. 2 may be carried out by software of a microcomputer or by firmware.

[0051]

Here, the specific control operation of the aforementioned plate stage position and speed control system L1 is described based on Fig. 3 while referring to Fig. 2. Here, the switch circuit 42 is OFF.

[0052]

When the signal of the reference position P_{ref} of the plate stage PST is output from the reference position output unit 26, the position deviation is calculated which is the difference of this reference position P_{ref} and the Y position information S0 from the first interferometer 24 for plate use; with this position deviation as an operating signal, the P controller 50 performs proportional control operation, and as a result, a speed instruction value is provided to the subtractor 52 from the P controller 50. The subtractor 52 calculates the speed deviation, which is the difference of this speed instruction value and the actual speed of the moving table 22 which is output of the integration circuit of Fig. 3 (in actuality, the speed of the moving table 22 which was found by means of differencing the previous sample value of the position of the moving table 22 and the present sampling value, calculated by the difference unit 40 of Fig. 2), the adder 53 adds this speed deviation and the instruction speed V_{ref}, and the PI controller 54 performs, with the instruction speed V_{ref} to which was added the speed deviation, as an operating signal, the combined control operations of PI control operation and phase lead compensation

control. As a result, a predetermined thrust instruction value (control amount) from the PI controller 54 is output from the adder 55. To this adder 55, the thrust value (control amount) that converts the instruction acceleration α_{ref} by means of the operation of a gain $M_P/K1$ (this is the gain corresponding to a value excluding the mass M_P of the plate stage PST by a thrust conversion gain K1, mentioning below), is input. Then, in the adder 55, the output from the gain $M_P/K1$ and the output from the plate stage servo operating unit 32 are added. Then, the control amount (thrust instruction value) which is the output of this adder 55 is converted by means of the thrust conversion gain K1 to a force F. This force F, as is clear from Fig. 3, corresponds to the sum of the thrust conversion value ($M_P \cdot \alpha_{ref}$) of the acceleration α_{ref} which was a feed-forward input from the reference value output unit 26, and of the thrust conversion value of the output of the plate stage servo operating unit 32.

[0053]

Here, when describing the correspondence of the operation of the aforementioned thrust conversion gain K1 and the actual phenomena, the equivalent is that the thrust instruction value from the adder 55 is provided to the plate stage drive amplifier 36 of Fig. 2, the plate drive signal S2 is provided from the said amplifier 36 to the linear motor 16, and the linear motor 16 generates the force F.

[0054]

Then, the plate stage PST is driven in the Y axis direction at α acceleration a corresponding to this thrust (F). The phenomenon, that is, the driving of the plate stage PST, in other words, the aforementioned thrust F, by means of the operation of the gain ($1/M_P$) corresponding to the reciprocal of the mass of the plate stage PST, is equivalent to being converted to an acceleration α. In Fig. 3, the gain ($1/M_P$) is shown as a constitutional element of the control system.

[0055]

Then, the aforementioned acceleration α is successively converted to a speed and a position by the integrating circuits 56, 58. The speed information is input as a feedback to the subtractor 52, and in addition, the position information S0 is input as a feedback to the aforementioned subtractor 28. By means of the plate stage position and speed control loop L1, the position and speed control of the plate stage PST is performed such that the position deviation, which is the difference of the reference position P_{ref} and the position information S0 from the plate use interferometer 24, becomes zero.

[0056]

In the present preferred embodiment, in addition to the reference position P_{ref}, the instruction speed V_{ref}, and the instruction acceleration α_{ref} are fed as inputs to the plate stage position and speed control system L1 (see Fig. 3). Thus, by controlling the plate stage PST by speed and acceleration feed-forward in addition to the feedback loop of the position of the plate stage, the frequency performance of the whole system containing the plate stage PST is caused to increase, the controllability of the plate stage PST by means of the control device 11, such as, position control responsiveness, can be further increased.

[0057]

Moreover, the integrating circuits 56, 58 of Fig. 3 do not in fact exist, the speed signal which is the output of the integrating circuit 56 is the output of the difference unit 40, the output S0 of the integrating circuit 58 is the output of the interferometer 24. However, in Fig. 3, according to the conventional manner of drawing control loops, integrity circuits 56, 58 are shown in the drawing.

[0058]

Furthermore, the specific control operation of the mask stage position control system L2 is described based on Fig. 3 with continued reference to Fig. 2.

[0059]

When the position information S1 is input from the second interferometer 25 for plate to the subtractor 44, the position deviation, which is the difference of the position information S1 and the Y position information S3 from the mask use interferometer 18, is calculated by the subtractor 44. Next, the PI controller 46 performs a PI control operation with this position deviation as an operating signal, with the result that a predetermined control amount (control amount corresponding to the mask stage drive signal S4 of Fig. 2) is output from the PI controller 46. Then, this control amount is converted into a force F' by means of a thrust conversion gain K2. When the operation of this thrust conversion gain K2 is described in correspondence with the actual phenomenon, a predetermined control amount from the PI controller 46 is provided to the mask stage drive amplifier 48 of Fig. 2, a mask stage drive signal S4 is provided from the amplifier 48 to the linear motor 14, and is equivalent to the linear motor 14 generating a thrust F'.

[0060]

Then, the mask stage MST is driven in the Y axis direction at an acceleration corresponding to this thrust (F'). By means of operating a gain ($1/M_M$) corresponding to the reciprocal of the mass of this mask stage MST, it is equivalent to conversion to an acceleration ß with such a meaning, the gain ($1/M_M$) is shown in Fig. 3 as a constitutional element of the control system.

[0061]

Then, the aforementioned acceleration ß is successively converted to a velocity and a position by the integrating circuits 60, 62, position information S3 is input as a feedback to the subtractor 44 by this means, and by means of the mask stage position control loop L2, following control of the mask stage MST with respect to the plate stage PST is performed such that the position deviation, which is the difference of the position information S1 from the second interferometer 25 for plate use and the position information S3 from the mask use interferometer 18, becomes zero.

[0062]

The exposure device 10 in the present embodiment, during scanning exposure, by means of a stage control device equivalent to the aforementioned control system of Fig. 3, fixed speed control of the plate stage PST and following control of the mask stage with respect to the plate stage PST, are performed based on the reference position (corresponding to the variable speed instruction) from the reference value output unit 26.

[0063]

In this case, the Y position information S0 of the moving table 22 from the first interferometer 24 for plate is input in the plate stage position and speed control system L1 as plate stage position information. As such, due to the existence of the Z · θ drive mechanism 20, even if a mechanical natural frequency arises between the moving table 22 and the plate table 19, because the aforementioned natural vibration is not included as a resonant mode in the aforementioned plate stage position and speed control system L1, the servo response band can be enlarged, resulting increase of the plate stage control performance.

[0064]

In Figs. 4(A) and (B), the gain characteristic and phase characteristic (Bode diagram) are respectively shown in the frequency response characteristics of a stage control device according

to the present embodiment obtained by simulation results with the aforementioned natural vibration frequency taken as 60 Hz.

[0065]

In Fig. 4(A), the symbol G1(f) shows the gain characteristic showing the response of the system with respect to the reference position (input) in the case that a measurement value of the interferometer 24 is output; the symbol G2(f) shows the gain characteristic showing the response of the system with respect to the reference position (input) in a case in which the position value of the interferometer 25 was output. Moreover, in Fig. 4(B), P1(f) and P2(f) respectively show the position characteristic with respect to G1(f) and G2(f) in Fig. 4(A).

[0066]

As can be gathered from G2(f) of Fig. 4(A), in the present embodiment, the servo response band becomes about 20 Hz, which is increased by about 10 Hz when compared with the gain characteristic of Fig. 7(A).

[0067]

Namely, in the preferred embodiment, the response band is enlarged in comparison with the prior art case up to higher frequency components, and because the system can faithfully follow inputs, as a result, it is possible to shorten the adjustment time with respect to the reference scanning speed of the plate stage. In other words, when the adjustment time is set as the same time, the reference scanning speed of the plate stage PST can be a higher speed.

[0068]

Moreover, by means of increasing the aforementioned response band, the overshoot and undershoot after the end of the variable speed of the plate stage can be made small, the following control performance of the mask stage MST with respect to the plate stage PST, which is performed by means of the mask stage position control loop L2 with the position of the plate table 19 as a reference value, is increased. Accordingly, the uniform speed synchronous adjustment time of the plate stage PST and the mask stage MST in order for scanning exposure is shortened, and it becomes possible to increase the scanning speed of both the stages MST, PST. Furthermore, the control performance of the plate stage PST and the following performance of the mask stage MST with respect to the plate stage PST are raised, with the result that during uniform speed control of both stages during exposure, uniform speed control of both stages can be realized which is closer to the ideal and by this means the superposition accuracy of the mask

and plate can be increased, and it is possible to increase the pattern transfer accuracy, namely the exposure accuracy.

[0069]

Moreover, in the present embodiment, by means of performing position control of the moving table 22, in order to realize position control of the plate stage PST, strictly speaking, variability of the position of the plate table 19 and the position of the moving table 22 arises, but during the scanning exposure, because synchronous control of mask and plate is realized by means of plate stage fixed speed control by the projection optical system PL reference and the following control of the mask stage with respect to this plate stage, no disadvantage arises as a result.

[0070]

Furthermore, during alignment time and the like, in the case that strict position setting of the plate stage PST is necessary, by means of setting ON the switch circuit 42 which constitutes the compensation system C1 by means of the main control device not shown in the drawing after the end of half speed reduction after movement, the difference of the plate table position and the moving table position is integrated by time by means of operating unit 38, and this integrated value is input as a feed-forward correction value to the plate stage position control loop LL1, to cause the plate table 19, not the moving table 22, to accurately stop in the reference position P_{ref}.

[0071]

Furthermore, an illuminating optical system constituted by plural lenses, and the projection optical system is built into the exposure device body to make an optical adjustment, and in addition, a mask stage and a plate stage consisting of plural mechanical components come into contact with wiring or piping mounted in the exposure device body, and coordinated adjustment (electrical adjustment, operation confirmation and the like) is made to manufacture the exposure device of this embodiment. The manufacture of the exposure device is preferably carried out by providing and assembling component parts in a clean room in which temperature and cleanliness are controlled.

[0072]

Furthermore, in the aforementioned embodiment, the case has been described suited to scanning type exposure device of the uniform batch magnification transfer type for a liquid crystal, but is not limited as to this, and can, of course, be suitable for application to step and repeat types of liquid crystal steppers, step and scan types of liquid crystal steppers,

semiconductor steppers, scanning steppers, and the like. Moreover, it can also be applied to a longitudinal type exposure device which supports a mask M and plate P along the vertical direction.

[0073]

As aforementioned, with the stage device according to the invention, because the position control function of the plate stage can be caused to rise, in particular, in the case of application of the present invention to a stepper or scanning stepper and the like sequential movement type of exposure device, it is possible to raise the throughput and to raise the position setting performance in the stepping time between shots and in the movement time to the alignment position. In particular, in raising the position setting of the plate stage, it is preferable to equip the compensation system similarly to the compensation system C1 in the aforementioned embodiment.

[0074]

It is also possible to apply the stage device according to the invention to an electron beam exposure device or an X-ray exposure device and the like exposure devices, a device which is equipped with a plate stage which supports the plate and moves, for example, a laser repair device and the like.

[0075]

[Efficacy of the Invention]

As explained above, according to each invention described in claims 1-3, there is an effect that the control performance of the stage can be increased by avoiding effects of mechanical natural vibrations.

[0076]

In addition, according to the invention described in claim 4, there is an effect that the control performance of the second stage for adjustment of positional relationships of the second stage with respect to the first stage can also be increased.

[0077]

Moreover, according to each invention described in claims 5 and 6, there is an excellent effect that increase of throughput and transfer accuracy of patterns can be achieved.

[Brief Description of Drawings]

[Fig. 1]

Fig. 1 is a schematic diagram of an exposure device provided in accordance with a preferred embodiment of the present invention;

[Fig. 2]

Fig. 2 is a block diagram of the stage control device depicted in Fig. 1;

[Fig. 3]

Fig. 3 is a block diagram of a control device corresponding to the stage control device depicted in Fig 2;

[Fig. 4]

Figs. 4(A) and 4(B) respectively show gain and phase (i.e., Bode diagrams) frequency response characteristics of a stage control device according to the present preferred embodiment obtained by simulation results with a natural vibration frequency taken as 60 Hz;

[Fig. 5]

Fig. 5 is a schematic diagram of a prior art exposure device;

[Fig. 6]

Fig. 6 is a block diagram of a prior art stage control device;

[Fig. 7]

Figs. 7(A) and (B) are Bode diagrams showing, in the prior art stage control system (specifically, the plate stage position control loop), in the frequency response characteristics, the gain characteristics, phase characteristics, in the case that the frequency of the natural vibration was 60 Hz;

[Description of Symbols]

10...Exposure device, 16...Linear motor (drive mechanism), 16b...Movable element (movable part), 19...Plate table (second portion), 22...Moving table (first portion), 24...First interferometer for plate (first position measuring device), 25...Second interferometer for plate (second position measuring device), PST...plate stage (first stage), L1...Plate stage position/speed control system (first stage control system), MST...mask stage (second stage), L2...Mask stage position control system (second stage control system), P...Plate (object, plate), M...Mask.

[Name of Document] Abstract

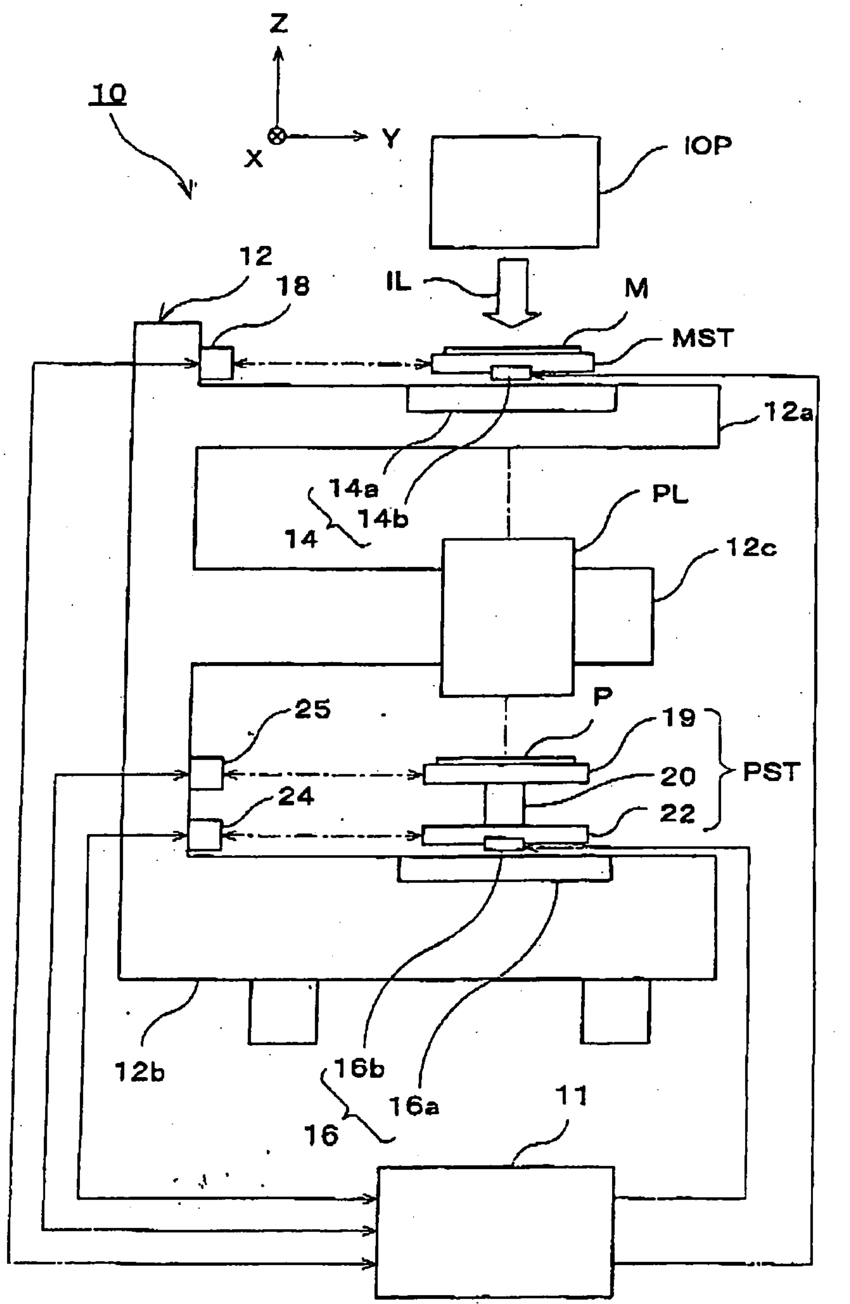
[Abstract]

[Object] To increase control performance of a stage

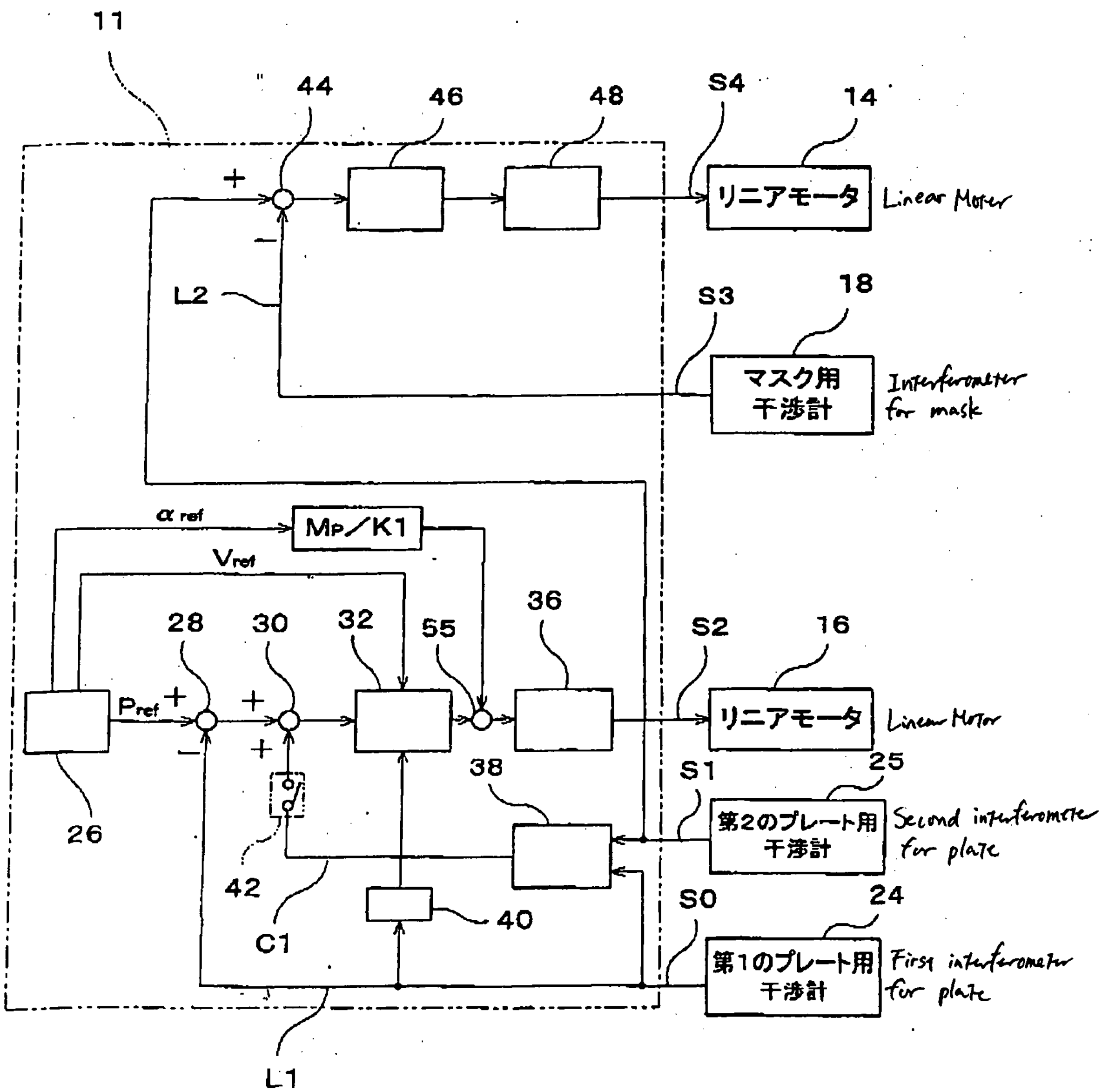
[Resolution Means] A first stage PST has a first portion 22 to which a movable element 16b of a drive mechanism 16 is provided, and a second portion 19 that supports an object P, and is driven in a Y-axis direction by the drive mechanism. A control device 11 controls position of the object 19 via the drive mechanism 16 based on measurement results of an interferometer 24 that measures position of the first portion 19. As a result, even if mechanical natural vibration is generated by any causes between the first portion 22 and the second portion 19, because the mechanical natural vibrations are not included as a resonance mode in the position control system that controls the position of the first stage, the response band of the stage control system can be widen. Therefore, the control performance of the first stage can be increased by avoiding the effects of the mechanical natural vibrations.

[Selected Figure] Fig. 1

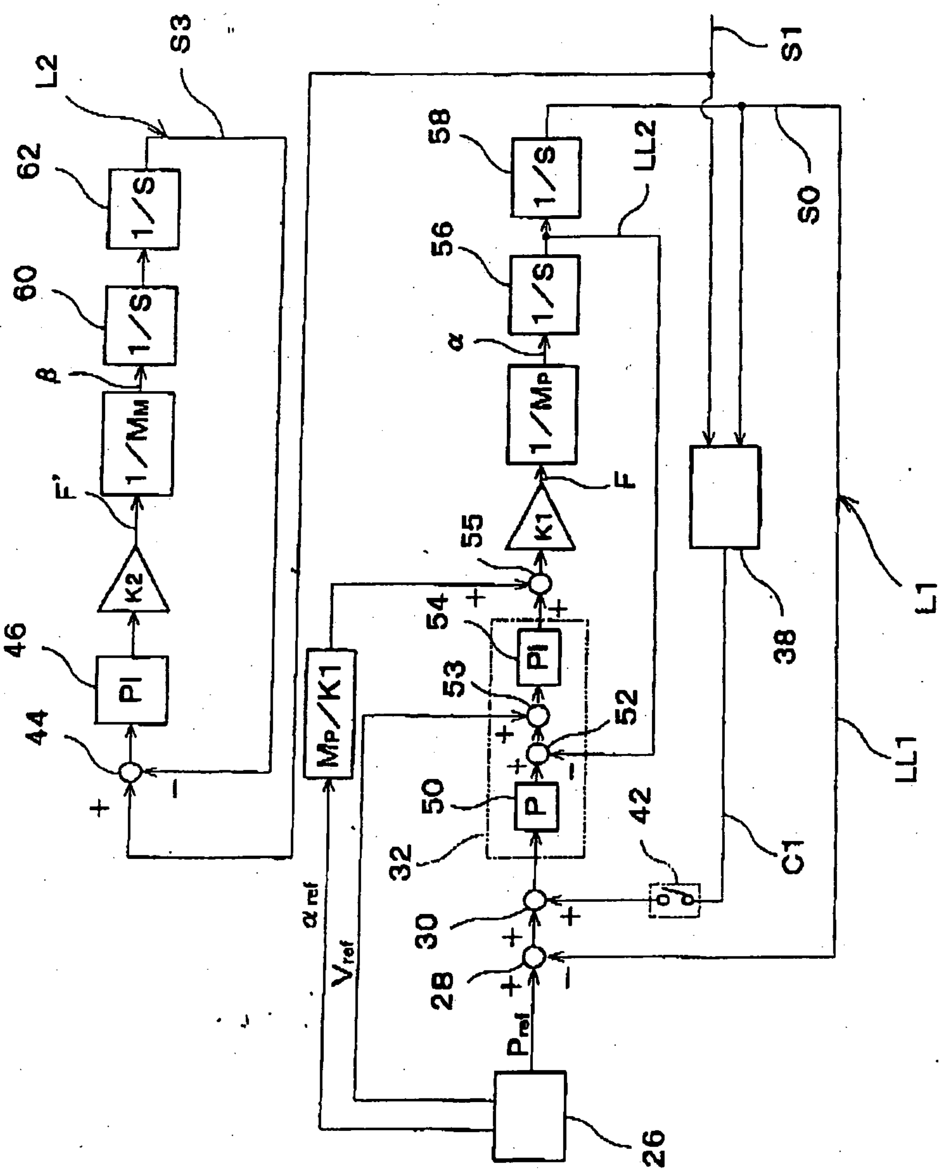
【書類名】　図面
〔Name of Document〕　Figures
【図１】
〔Fig. 1〕



【図２】
[Fig. 2]

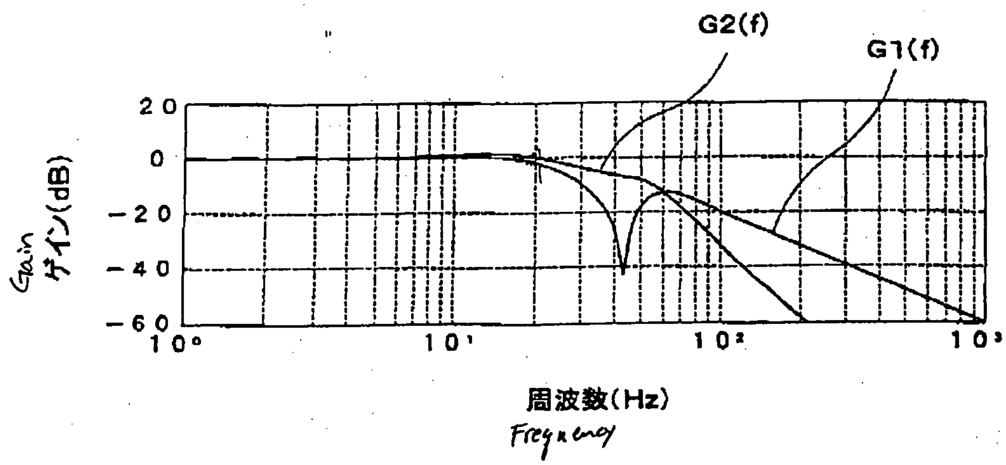

11
44
46
48
S4
14
+
−
リニアモータ
Linear Motor
L2
S3
18
マスク用
干渉計
Interferometer for mask
α ref
MP／K1
Vref
28
30
32
55
36
S2
16
Pref
+
+
+
−
リニアモータ
Linear Motor
38
S1
25
第２のプレート用
干渉計
Second interferometer for plate
26
42
C1
40
S0
24
第１のプレート用
干渉計
First interferometer for plate
L1

【図３】
[Fig.3]

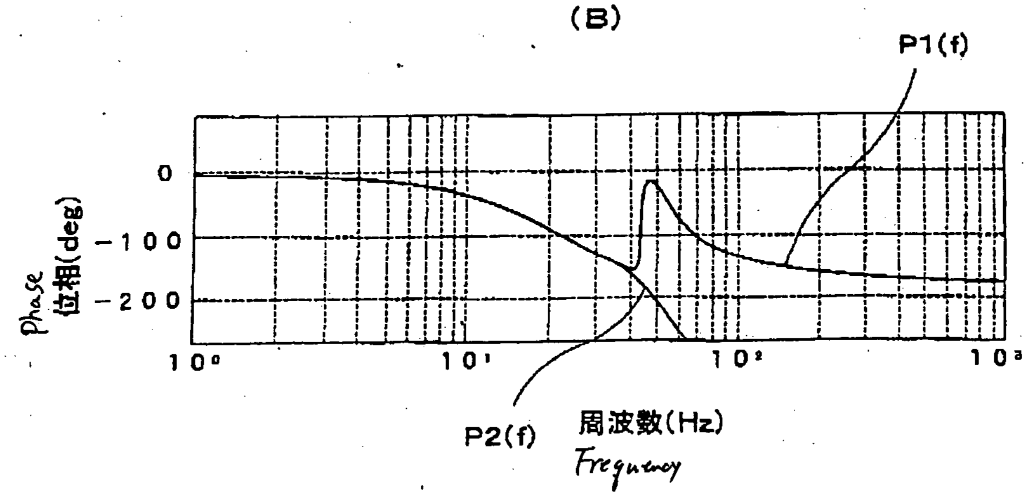

S1
S3
L2
62
1／S
60
1／S
β
1／MM
F'
K2
46
PI
44
+
-
58
1／S
LL2
56
1／S
α
1／MP
F
K1
55
+
+
54
PI
53
+
52
+
-
50
P
32
MP／K1
αref
Vref
30
+
+
28
+
-
Pref
26
S0
38
L1
LL1
C1
42

【図４】
〔Fig.4〕

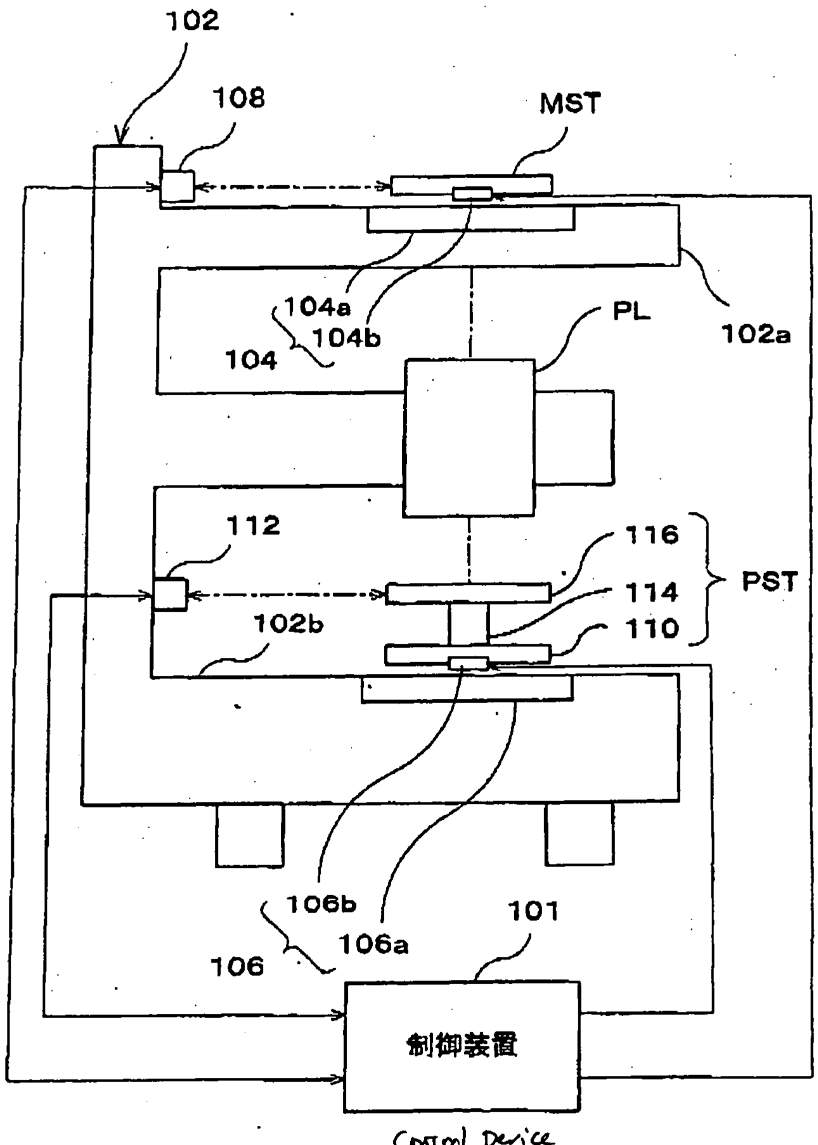
(A)


G2(f)
G1(f)
20
0
－20
－40
－60
Gain
ゲイン(dB)
10^0
10^1
10^2
10^3
周波数(Hz)
Frequency

(B)


P1(f)
0
－100
－200
Phase
位相(deg)
10^0
10^1
10^2
10^3
P2(f)
周波数(Hz)
Frequency

【図５】
[Fig. 5]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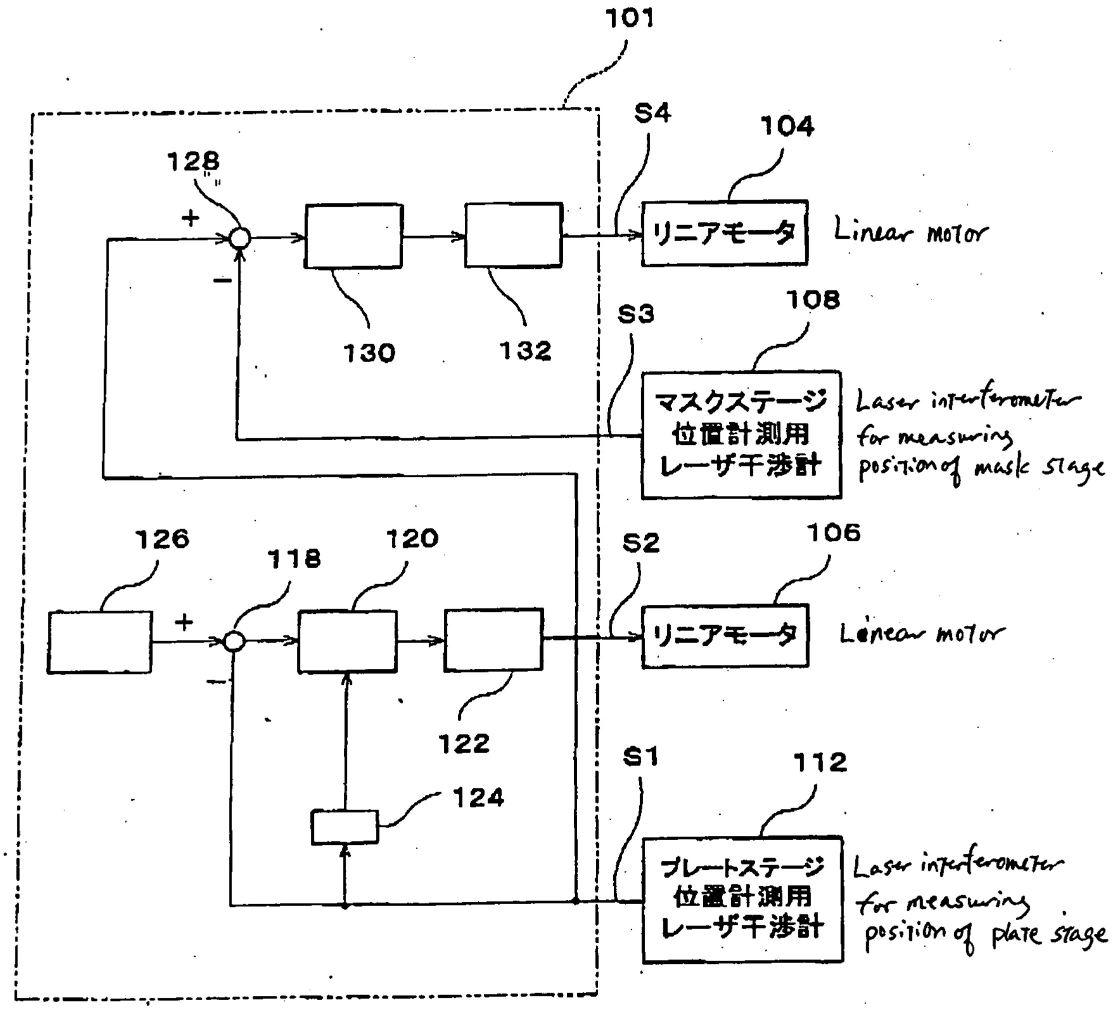
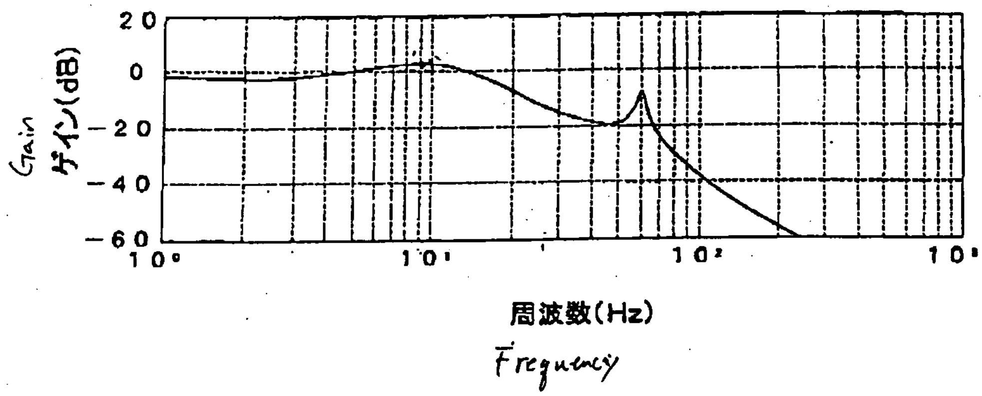
108
MST
104a
104b
104
PL
102a
112
116
114
110
PST
102b
106b
106a
106
101
制御装置
Control Device

【図６】
[Fig. 6]

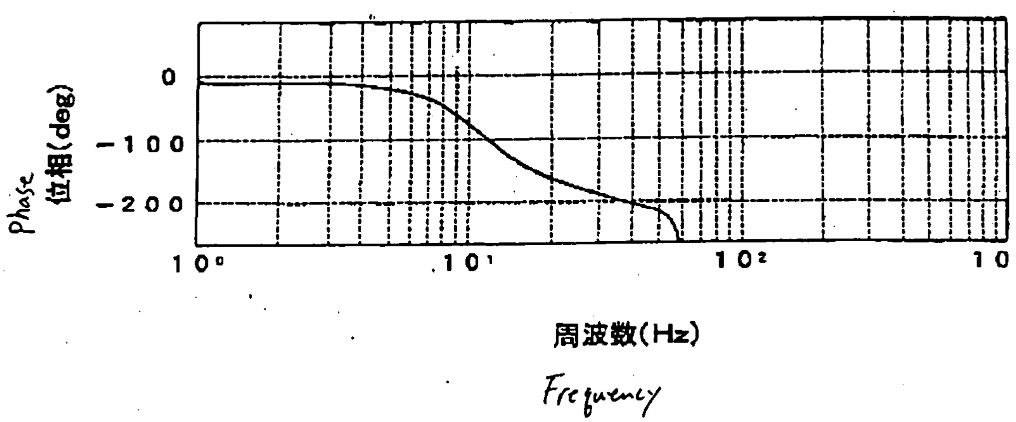

101
S4
104
128
+
−
130
132
リニアモータ
Linear motor
S3
108
マスクステージ
位置計測用
レーザ干渉計
Laser interferometer for measuring position of mask stage
126
118
120
S2
106
リニアモータ
Linear motor
122
S1
112
124
プレートステージ
位置計測用
レーザ干渉計
Laser interferometer for measuring position of plate stage

【図７】
[Fig.7]

(A)


20
0
−20
−40
−60
ゲイン(dB)
Gain
10⁰
10¹
10²
10³
周波数(Hz)
Frequency

(B)


0
−100
−200
位相(deg)
Phase
10⁰
10¹
10²
10³
周波数(Hz)
Frequency